

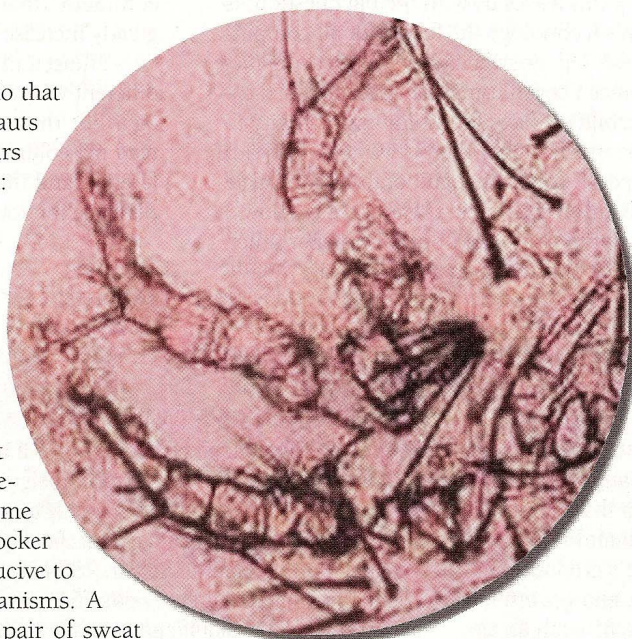
Lab-on-a-chip finds jobs for Mr. Clean

Here is a possible scenario that could confront astronauts traveling back from Mars after a three-year mission: The spacecraft develops intermittent electrical shorts. During a check of the wiring behind a little-used service panel, they find a grapefruit-sized globule of dirty liquid. On the wiring the astronauts spot mold. It would seem that a spacecraft is no different in some respects from a steamy locker room—both can be conducive to the growth of microorganisms. A pair of sweat socks is a pair of sweat socks, whether on the space station or in a high-school locker.

The discovery of a large globule of dirty water—in this case, one closer to the size of a basketball—actually did occur on the Russian space station Mir. When Mir was orbited in 1986, “it was as clean as the International Space Station when it was launched,” recalls C. Mark Ott, health scientist at NASA Johnson. Moreover, the cosmonauts aboard Mir followed a regular schedule of cleaning all the station’s surfaces to prevent the growth of bacteria and molds that could jeopardize human health. Astronauts from the U.S. and other nations aboard ISS follow the same cleaning procedures. But wherever humans venture, microorganisms follow—and grow, if conditions are right.

Assessing the problem

In the late 1990s, NASA joined the Russian space program in its evaluation of the microbial activity aboard Mir. In order to plan better for long-duration missions, the scientists wanted to learn about the



Astronauts found this dust mite floating in a globule of water on board Mir. Other microorganisms collected include protozoa and amoebae.

kinds of organisms that can grow in a spacecraft that is occupied for long periods, and where air and water are recycled. One reason they were so interested was that during its 15 years in LEO, Mir had had the misfortune of suffering several power outages. The temperature and humidity inside the station during these outages rose well above normal levels. In addition, air circulation was inadequate until the electricity was restored.

In 1998, U.S. astronauts participating in the NASA 6 and NASA 7 visits to Mir collected air and surface samples from the station’s control center, dining area, sleeping quarters, hygiene facilities, exercise equipment, and scientific equipment. When they opened a rarely accessed service panel in Mir’s Kvant-2 Module, they discovered a large free-floating mass of

water. “According to the astronauts’ eyewitness reports, the globule was nearly the size of a basketball,” Ott says.

Moreover, the mass of water was only one of several that were hiding behind different panels. Scientists later concluded that the water had condensed from humidity that accumulated over time as water droplets coalesced in microgravity. The pattern of air currents in Mir carried air moisture preferentially behind the panel, where it could not readily escape or evaporate.

Nor was the water clean: Two samples were brownish and a third was cloudy white. Behind the panels the temperature was a warm 82 F (28 C), an ideal temperature for growing all kinds of microorganisms. When the samples were extracted from the globules by syringes and returned to Earth for analysis, they were found to contain several dozen species of bacteria and fungi, plus some protozoa, dust mites, and possibly spirochetes.

In addition, the astronauts aboard Mir found colonies of organisms growing on “the rubber gaskets around windows, on the components of space suits, cable insulations, and tubing, on the insulation of copper wires, and on communications devices,” says Andrew Steele, a senior staff scientist at the Carnegie Institution of Washington. He has been working with other investigators at NASA Marshall.

Aside from being unattractive and an issue for human health, such organisms can attack the structure of a spacecraft itself. “Microorganisms can degrade carbon steel and even stainless steel. In corners where two different materials meet, they can set up a galvanic [electrical] circuit and cause corrosion,” says Steele. “They can produce acids that pit metal, etch glass, and make rubber brittle. They can also foul air and water filters.”



LOCAD-PTS is a handheld biological laboratory.

In short, germs can be as bad for a spacecraft's health as for crew health.

Help from a handheld lab

The need to determine the nature of the microorganisms found on the space station is one reason Marshall is developing the LOCAD-PTS, or Lab-on-a-Chip Application Development-Portable Test System. This handheld device can detect the presence of bacteria or fungi on the surfaces of a spacecraft within minutes—far more rapidly than standard methods of culturing, which can take several days and may require a return to Earth for further analysis.

"LOCAD-PTS is an excellent example of the kind of hardware astronauts will need to be autonomous in a lunar habitat or a long-duration mission to Mars," says Steele. "Crews must be able to make assessments on their own. They may not be able to get samples back to Earth." Although no electrical or mechanical failure on Mir was specifically traced to biodegradation, "it is not a chance you would want to take en route to Mars," he says.

An early version of LOCAD-PTS can test for one major category of bacteria called Gram-negative, which accounts for about half of all bacterial species. The device is being tested aboard ISS right now. New cartridges for the unit, due to be sent up to ISS in early 2008, will be able to test for almost all major categories of bacteria (Gram-positive as well as Gram-negative) and also for fungi. This fall Steele plans to test an even more advanced version in the Arctic. The newer version will be able to sense 130 specific microorganisms, not just broad categories.

Ultimately, NASA plans to develop a handheld device that can identify thousands of individual microorganisms. "The arrays of tests on LOCAD-PTS can be tailored to look at specific questions," Steele says. "For example, one array might look for genes and chemical compounds associated with biodegradation of a spacecraft's structure, whereas another array might look for human pathogens, or try to detect life on Mars."

By getting the results of the tests in minutes, astronauts would know which cleaning compound will work best to prevent a spacecraft or habitat from "falling ill."

Putting it to the test

An astronaut used the LOCAD-PTS for the first time at the end of March aboard the ISS. The device had been launched last December 9 on board the space shuttle Discovery, then stowed aboard ISS until its scheduled experiment time on March 31.

Astronaut Sunita "Suni" Williams opened the instrument kit bag, assembled LOCAD-PTS, and then took six readings. "The first two readings were controls to show that the instrument was operating correctly," says Jake Maule, LOCAD-PTS project scientist at the Carnegie Institution of Washington. "First she swabbed her palm, which she had pressed to handrails and other often-handled surfaces that should have had lots of bacteria, and indeed, we got a strong positive reading," he continues. "Then she sampled some ultraclean water in the instrument that is used to moisten samples, to check that the water was truly clean, and indeed, we got a great negative reading."

Next, Williams chose a wall panel in ISS Node 1 to test using both LOCAD-PTS and, for comparison, a standard culturing method.

For the standard method, she first pressed a layer of solid gel growth medium (similar to agar) against the panel for a few seconds, replaced it securely in its packaging, then set it aside to incubate for a few days. Then she took a dry swab (similar to a high-tech Q-tip)

from LOCAD-PTS and rubbed it on the panel next to the same area. Flushing ultraclean water through the swab converted the sample to liquid form, and a few drops were dispensed into the handheld LOCAD-PTS instrument.

"The cleaner the sample, the longer the analysis takes," Wainwright says. "Because this site was pretty clean, it took about 12 min, but dirty samples can take as little as a couple of minutes."

It was during the wait that Williams must have noted the time. Although it was 10:20 p.m. CDT at NASA Marshall, where all the LOCAD-PTS scientists were anxiously watching television monitors, it was actually past midnight on April 1, GMT, the time zone used by ISS.

"Suni said, 'Ah, this last set of readings for LOCAD-PTS looks a bit strange,'" Maule recalls. "After a pause of about five seconds she exclaimed, 'Happy April Fools' Day! The numbers are just fine.'"

"She definitely got me!" says Maule.

The experiment had been a resounding success. "What a huge relief," says Norman Wainwright of the Charles River Laboratories in Charleston, S.C., and the experiments' principal investigator. "The whole technical team was delighted that it worked so well."

Future plans

Over the next few months, LOCAD-PTS and standard culture methods will be used to investigate different parts of ISS. "A second generation of LOCAD-PTS cartridges for the specific detection of fungi is scheduled to launch to ISS on space shuttle STS-123," says Anthony Lyons, LOCAD-PTS project manager at Marshall, the center that has overseen the project since its inception and supervised getting the equipment spaceflight-ready.

"With each generation of cartridges, we are getting more and more specific in what we detect," Lyons says. Our ultimate aim is to provide the crew with a selection of cartridges for the detection of a wide variety of target compounds, biological and chemical, both inside and outside the spacecraft—something that would be especially important for long-duration missions to the Moon or to Mars.

"Right now," says Lyons, "we are very happy with the first tests."

Edward D. Flinn
edflinn@pipeline.com